

Persistence and Geometry

Thomas Sattig
Department of Philosophy
University of Tübingen

Forthcoming in *Facets of Reality: Proceedings of the 45th International Ludwig Wittgenstein Symposium*, Y. Kappas, A. Passinsky, J. De Rizzo, and B. Schnieder (eds.), DeGruyter.

A conceptual framework of persistence characterizes different ways for something to persist through time. The mereological framework characterizes different modes of persistence in mereological terms, the locational framework in locational terms, and the individuation framework in terms of identity or essence. These are the most widely discussed frameworks. The aim of this paper is to motivate and develop a further conceptual framework of persistence. In Section 1, I will describe a simple case of a persisting material object and distinguish two ways for the object to persist. In Section 2, I will show that neither the mereological nor the locational nor the individuation framework captures the difference between the two modes of persistence. In Section 3, I will develop a new conceptual framework of persistence, which characterizes modes of persistence in geometrical terms, and which captures the target difference in the reference case.

1 Two modes of persistence

Lumi is a light source. For simplicity, we will treat it as an object without spatial depth. The room is dark. Lumi is the only visible object. Through a brief temporal interval Lumi persists and changes in colour from white to pink to turquoise, while remaining in the same place. *How* does Lumi persist through this interval? Consider the following two descriptions of how Lumi persists. First, Lumi persists in such a way that Lumi is point-shaped. This mode of persistence of Lumi is illustrated in Figure 1. (For ease of depiction, only three moments, t_1 - t_3 , are featured.)

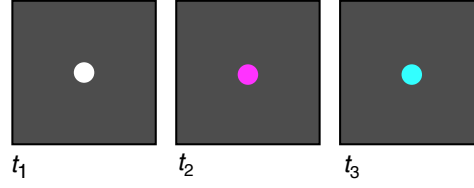


Figure 1: First mode of persistence

Second, Lumi persists in such a way that Lumi is line-shaped. This mode of persistence of Lumi is illustrated in Figure 2.

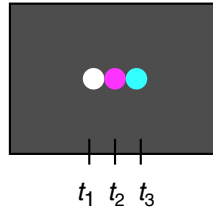


Figure 2: Second mode of persistence

These are incompatible modes of persistence since nothing can be both point-shaped and line-shaped. The two modes of persistence are picked out by how Lumi's persistence, its temporal extension, is related to Lumi's shape. These relationships can be described more carefully as follows:

First mode of persistence of Lumi: the dimensionality of the temporally extended object's shape does not match the dimensionality of its temporal interval. Lumi's shape is zero-dimensional, whereas the temporal interval is one-dimensional.

Second mode of persistence of Lumi: the dimensionality of the temporally extended object's shape matches the dimensionality of its temporal interval. Both Lumi's shape and its temporal interval are one-dimensional.

This initial description of Lumi's two modes of persistence can be put into sharper focus by comparing Lumi with Sumi. Sumi is a spatially extended light source with the shape of a line. The room is dark. Sumi is the only visible object. At a given moment, Sumi is extended across a certain region of space and Sumi has different colours across that region. This scenario is illustrated in Figure 3. (For ease of depiction, only three spatial points, p_1 - p_3 , are featured.)

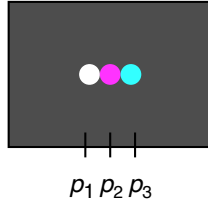


Figure 3: Spatial extension

Sumi is spatially extended in such a way that it is line-shaped. We can put the relationship between Sumi’s spatial extension and Sumi’s shape more carefully as follows:

Spatial extension of Sumi: the dimensionality of the spatially extended object’s shape matches the dimensionality of its spatial region. Both Sumi’s shape and its spatial region are one-dimensional.

Comparing Sumi’s way of being spatially extended with Lumi’s first and second modes of being temporally extended, we find that Lumi’s first mode of persistence is *non-spacelike*, whereas Lumi’s second mode of persistence is *spacelike*.

Lumi’s two modes of persistence are both familiar. Lumi’s first, non-spacelike mode of persistence corresponds to how the case would be described pre-theoretically. Lumi’s second, spacelike mode of persistence corresponds to how the case would be described in a physics textbook. What does the difference between Lumi’s two modes of persistence consist in? This is the question to be discussed in this paper. An account of the difference should ultimately help to explain why Lumi’s first mode of persistence corresponds to how Lumi seems to persist to human perceivers and why Lumi’s second mode of persistence corresponds to how contemporary physics conceives of space and time. But I will not go this far here. I will give an account of what the difference consists in, leaving further development and application of the account for future work. In Section 2, I will argue that neither of the mainstream approaches to persistence offers an illuminating account of the target difference in Lumi’s case, and hence that the explanation of the difference poses a real challenge in the metaphysics of persistence. In Section 3, I will develop a new conceptual framework of persistence, which characterizes modes of persistence in geometrical terms, and which offers an illuminating account of the target difference.

2 The mereological, locational, and individational frameworks of persistence

A conceptual framework of persistence characterizes different ways for something to persist through time, different modes of persistence. Several frameworks of persistence have been characterized in the metaphysics of persistence over the past four decades or so. In seeking an account of Lumi's two modes of persistence, we should look to them for answers.

The *mereological* framework of persistence explains different modes of persistence of a material thing in terms of the thing's parts. The framework offers an account of a spacelike mode of persistence, known as *perdurance*, and a non-spacelike mode of persistence, known as *endurance*. For a thing to perdure through an interval, T—that is, for a thing to be spacelike temporally extended through T—is for the thing to have different *temporal parts* at the different moments in T. Analogously, a thing is spatially extended in virtue of being composed of different spatial parts. By contrast, for a thing to endure through T—that is, for a thing to be non-spacelike temporally extended through T—is for the thing to be wholly present at each moment in T. This is the original formulation.¹ Since the notion of being wholly present has since fallen out of favour,² friends of the mereological framework have adopted a more cautious analysis of endurance: a thing exists at different moments, but it does not exist at these moments by having different temporal parts at the different moments.³

The *locational* framework of persistence explains different modes of persistence of a material thing in terms of how the thing is located in time. Moments and intervals of time are here treated in analogy with points and regions of space. A moment is a temporal point and an interval is a temporal region. For a thing to perdure through a temporal region—that is, for a thing to be spacelike temporally extended through the region—is for the thing to be exactly and uniquely located at this region, just as a thing is spatially extended by being exactly and uniquely located at a spatial region. Moreover, for a thing to endure through a temporal region—that is, for a thing to be non-spacelike temporally extended through the region—is for the thing to be exactly located at each temporal point in the region, but not at the whole region. Thus, while a perduring

¹ See (Lewis 1986, 202-204).

² See (Sider 2001, 63-68).

³ See (Wasserman 2016) for an overview.

thing has a unique exact temporal location, an enduring thing is temporally multi-located.⁴

The *individuation* framework of persistence, as I will call it, explains different modes of persistence of a material thing in terms of the thing's *identity*, *nature*, or *essence*—in short, in terms of what ‘individuates’ a thing. Roughly, for a thing to endure—that is, for a thing to be non-spacelike temporally extended—is for the thing's identity to be *temporally local*. That is, if a thing exists at a moment t , then the factors that determine the thing's identity all obtain at t . Moreover, for a thing to perdure—that is, for a thing to be spacelike temporally extended—is for the thing's identity to be *temporally non-local*. That is, if a thing exists at t , then the factors that determine the thing's identity reach beyond t .⁵

These are the three best known frameworks of persistence, presented in the order in which they appeared on the scene. I will now apply each of them to the case of Lumi, and I will ask whether the frameworks capture the difference between Lumi's first, non-spacelike mode of persistence and Lumi's second, spacelike mode of persistence. I will argue that neither of the frameworks succeeds in this task. For reasons that will become apparent shortly, I will begin with the locational framework.

2.1 Application of the locational framework

The task is to give an account of a difference concerning persistence that sustains a related difference concerning shape. In other words, we are considering the nature of persistence through the lens of shape. Can the target difference be explained on the basis of the distinction between locational endurance and perdurance? Let us apply the locational framework to Lumi's first, non-spacelike mode of persistence and to Lumi's second, spacelike mode of persistence, respectively:

Locational account of Lumi's first mode of persistence: the dimensionality of Lumi's shape does not match the dimensionality of its interval because Lumi is exactly located at each moment in the interval, but not at the whole interval.

⁴ The locational approach was introduced in (Gilmore 2006) and (Sattig 2006); see also (Gilmore 2008), (Parsons 2008), and (Eagle 2016).

⁵ The individuation approach is stated in terms of identity in (Hofweber and Velleman 2011). In (Sattig 2023), a different variant is developed, which employs the neo-Aristotelian concept of a thing's mereological structure that is encoded in the thing's essence.

Locational account of Lumi's second mode of persistence: the dimensionality of Lumi's shape matches the dimensionality of its interval because Lumi is exactly and uniquely located at the interval.

This account of Lumi's second mode of persistence is analogous to the standard locational account of Sumi's spatial extension: the dimensionality of Sumi's shape matches the dimensionality of its spatial region because Sumi is exactly and uniquely located at its spatial region.

I will now sketch a natural picture of how an object's temporal location relates to the object's geometrical attributes and to the object's geometrical shapes. According to this picture, Lumi's locational difference in the two versions of the case is not sufficient for Lumi's shape difference.

Time is often conceived of as a geometrical space that is constituted by a set of geometrical points colloquially known as moments or instants. This set has a certain intrinsic *geometrical structure*. The points in the set constitute a line. This line has a certain intrinsic direction. Any two points of the space are connected by a segment of the line. The length of the line segment that runs between two points is the distance between these points. These basic assumptions concerning time's intrinsic geometrical structure will suffice for present purposes.

The system of time has certain *organizational functions*. These functions correspond to how we understand time pre-theoretically. Time's central functions are to organize a domain of material things in such a way that the things have a certain directed order and that the things are separated from each other by certain amounts of time. Given that time has an intrinsic geometrical structure, the system's organizational functions are realized as follows. Material things are embedded in time by being *exactly located* at points or moments of time. Exact location—or exact occupation—is the relation by which geometrical attributes of temporal points are transferred to the material inhabitants of time. For instance, a material thing *a* and another material thing *b* exist (or obtain) in separation by two seconds. What explains their temporal separation? Things are metrically separated in time in virtue of standing in relations of temporal distance to each other. Moreover, things inherit their temporal distances from their locations. Thus, *a* exists and *b* exists in separation by two seconds because *a* is exactly located at a moment t_1 , *b* is exactly located at a moment t_2 , and t_1 has the distance of two seconds to t_2 . When the system of time is conceived of as a geometrical

space whose geometrical structure is transferred to material things via exact location, then the system of time is a *system of location*.⁶

Temporal being and temporal separation in a temporal system of location are analogous to spatial being and spatial separation in a spatial system of location. The standard view of how familiar three-dimensional space organizes a domain of material things is that these things are exactly located at points or regions of a geometrically structured space, and that intrinsic geometrical attributes of the space are transferred to the inhabitants of the space by way of exact location. Thus, material things a and b are separated by two centimetres because a is exactly located at a spatial point p_1 , b is exactly located at a spatial point p_2 , and the shortest path between p_1 and p_2 has the length of two centimetres.

Let us turn to geometrical shapes of material objects. This is not the place to give a detailed account of the nature of a geometrical shape of a material object (or, more precisely, of the surface or boundary of a material object).⁷ A rough sketch will suffice. I will assume that a geometrical shape of a material object is a pattern of geometrical attributes of parts of the object. In the different versions of the Lumi-case, we find pre-theoretical descriptions of an object's being point-shaped and of an object's being line-shaped. This shape-talk can be clarified as follows. A material object, x , is point-shaped just in case none of the parts of x have a (positive) distance among each other. Moreover, a material object, x , is line-shaped just in case the parts of x are collinear. This rough account is close enough for present purposes. Notice that it admits line-shaped objects with spatial gaps.

In a system of location, the attributes of distance and collinearity are derived from the system's intrinsic geometrical structure via exact location. When object x is exactly located at point p , and object y is exactly located at point q , for any x and y and any p and q , and when p and q have distance d , for any d , then x and y have distance d . Moreover, a set of points is collinear just in case the set contains at least three points and all points in the set lie on the same line. Accordingly, when some objects, the x s, are exactly located at points that are collinear, then the x s are collinear. This is a pleasantly straightforward account of how ordinary descriptions of an object's being point-shaped and an object's being line-shaped are anchored in geometrical attributes of a system of location.

Back to Lumi. Let us start with Lumi's second mode of persistence, as conceived of in the locational framework: Lumi is exactly and uniquely located at

⁶ The conception of time as a system of location is introduced in (Sattig 2025, chaps. 3 and 7).

⁷ See (Sattig 2025, chap. 7) for more details.

a certain interval or temporal region, T . It is standard in the locational framework to conceive of perduring objects as having instantaneous temporal parts. This assumption is standard because it yields a simple and clear account of change over time. Recall, though, that while temporal parts are here invoked to explain change, they are not invoked to explain persistence. Persistence is a locational matter. Given that Lumi has different temporal parts that are exactly located at different moments in T , it is not the case that none of Lumi's parts have a (positive) distance among each other. For Lumi's different temporal parts are metrically separated. Thus, Lumi is not point-shaped. Moreover, since Lumi's temporal parts are collinear, Lumi is line-shaped. Thus, the dimensionality of Lumi's shape matches the dimensionality of Lumi's interval. So far, so expected.

Next, consider Lumi's first mode of persistence, as conceived of in the locational framework: Lumi is exactly located at each temporal point in interval T , but not at the whole of T . Consider two moments in T , t_1 and t_2 . Lumi is exactly located at each of them. Since t_1 and t_2 have a certain distance, it follows that Lumi has this distance to itself. Hence, Lumi is not point-shaped. This is a straightforward consequence of multi-location in a system of location. In such a system, intrinsic geometrical structure is transferred to material inhabitants via exact location. This is how a system of location organizes a material domain. In doing so, the system does not care *which* material thing is exactly located at *which* point or region in the system. The system's tasks concern geometry, not identity.⁸ When x and y are exactly located at distance-related points, then x and y are distance-related, whether x and y are two things or one thing. What holds for distance, holds for collinearity. The moments in T are collinear—they all sit on the timeline. Since Lumi is exactly located at each moment in T , Lumi exhibits the pattern of collinearity, and hence Lumi is line-shaped. It follows that the dimensionality of Lumi's shape matches the dimensionality of Lumi's interval. Lumi's endurance, as construed in the locational framework, does not correlate with the property of being point-shaped. I conclude that if the locational framework of persistence is clarified in terms of the concept of a system of location, then the locational framework does not capture the target difference between Lumi's first, non-spacelike and Lumi's second, spacelike modes of persistence.

⁸ See (Sattig 2025, chap. 7).

2.2 Application of the mereological framework

Does the mereological framework capture the target difference? Let us apply the framework to the case of Lumi:

Mereological account of Lumi's first mode of persistence: the dimensionality of Lumi's shape does not match the dimensionality of its interval because Lumi exists at the different moments in the interval in a manner that does not rely on Lumi's having different temporal parts at these moments.

Mereological account of Lumi's second mode of persistence: the dimensionality of Lumi's shape matches the dimensionality of its interval because Lumi has different temporal parts at the different moments in the interval.

This account of Lumi's second mode of persistence is analogous to the standard mereological account of Sumi's spatial extension: the dimensionality of Sumi's shape matches the dimensionality of its spatial region because Sumi has different spatial parts at the different parts of this region.

Here is a scenario in which the two versions of the Lumi-case are analysed along the lines of the mereological framework of persistence, but the mereological difference concerning persistence is not accompanied by the expected difference concerning shape. Let us begin with Lumi's second mode of persistence, as conceived of in the mereological framework: Lumi has different temporal parts at the different moments in the interval, T , through which it persists. Since this account is neutral with respect to matters of temporal location, we may assume that time is a system of location and that Lumi is exactly and uniquely located at T . While persistence is primarily a mereological matter, this is a locational background assumption often made by friends of mereological perdurance. Given that Lumi has different temporal parts that are exactly located at different moments in T , it is not the case that none of Lumi's parts have a distance among each other. For Lumi's different temporal parts are distance-related. Thus, Lumi is not point-shaped. Moreover, since Lumi's temporal parts are collinear, Lumi is line-shaped. In sum, the dimensionality of the temporally extended object's shape matches the dimensionality of its temporal interval. So far, so good.

Next, consider Lumi's first mode of persistence, as conceived of in the mereological framework: Lumi does not exist at the different moments in T by having different temporal parts at these moments. Since this account is neutral with respect to matters of location, we may assume that time is a system of

location and that Lumi is exactly located at each moment in T , but not at the whole of T . While persistence is a mereological matter, this is now a standard locational background assumption made by friends of mereological endurance. Since Lumi is itself exactly located at each moment in T , Lumi does not need any temporal parts to exist at these moments. Now consider two moments in T , t_1 and t_2 . Lumi is exactly located at both. Since t_1 and t_2 have a certain distance to each other, it follows that Lumi has this distance to itself. Hence, Lumi is not point-shaped. Similarly for collinearity. The moments in T are collinear. Since Lumi is exactly located at each moment in T , Lumi exhibits the pattern of collinearity, and hence Lumi is line-shaped. It follows that Lumi's first mode of persistence, as construed in the mereological framework, does not correlate with Lumi's being point-shaped. This means that the mereological approach to persistence is not sufficient to capture the target difference between Lumi's first, non-spacelike mode of persistence and Lumi's second, spacelike mode of persistence. For if the mereological framework is combined with the conception of time as a system of location, then the mereological version of Lumi's first mode of persistence—mereological endurance—is not accompanied by Lumi's being point-shaped.⁹

⁹ The *stage view*—see (Hawley 2001) and (Sider 2001)—is a sibling of mereological perdurantism. Might this approach help with the Lumi-case? Recall Lumi's second mode of persistence, as conceived of in the mereological framework: Lumi is an object that has different instantaneous temporal parts at the different moments in the interval, T , through which it persists. On the assumptions that time is a system of location, and that Lumi is exactly and uniquely located at T , it follows that Lumi is line-shaped. Now consider the following modification of this picture. There is a material object, o , that has different instantaneous temporal parts at the different moments in the interval, T , and that is exactly and uniquely located at T . As we saw, o , is line-shaped. Lumi is not identical with o . Lumi is just a single instantaneous temporal part of o . Lumi has itself and all other instantaneous stages of o as its *temporal counterparts*. Moreover, Lumi exists at a moment, t , in virtue of having a temporal counterpart at t . Finally, Lumi has a geometrical shape at a moment, t , in virtue of having a temporal counterpart at t , which has that shape. On this approach, Lumi is point-shaped at each moment at which Lumi exists. This counterpart-theoretic description does not give us what we want. Recall the two target descriptions of the Lumi case: the first description of the case is that the room is dark and the only visible object is always point-shaped; the second description is that a line-shaped object is visible. The counterpart-theoretic approach offers a description of some object called 'Lumi' as persisting while always being point-shaped. But this is insufficient to capture the first version of the case. For the counterpart-theoretic approach recognizes a line-shaped object where there is none.

2.3 Application of the individuation framework

Does the individuation framework capture the target difference? Let us apply the framework to the case of Lumi:

Individuation account of Lumi's first mode of persistence: the dimensionality of Lumi's shape does not match the dimensionality of its interval because Lumi's identity is temporally local in the sense that, for any moment, t , at which Lumi exists, the factors that determine Lumi's identity all obtain at t .

Individuation account of Lumi's second mode of persistence: the dimensionality of Lumi's shape matches the dimensionality of its interval because Lumi's identity is temporally non-local in the sense that, for any moment, t , at which Lumi exists, the factors that determine Lumi's identity reach beyond t .

Lumi's temporally non-local identity is analogous to Sumi's spatially non-local identity: given that Sumi is exactly located at a certain extended spatial region, r , Sumi, intuitively speaking, exists at or covers each point in r . But the factors that determine Sumi's identity are not spatially local in the sense that they do not obtain at any point in r .

Here is a scenario in which the two versions of the Lumi case are analysed along the lines of the individuation framework, while the individuation difference concerning persistence is not accompanied by the expected difference concerning shape. The scenario will be constructed in parallel to the counterexample in Section 2.2. Let us begin with Lumi's second mode of persistence, as conceived of in the individuation framework: Lumi's identity is temporally non-local in the sense that, for any moment, t , at which Lumi exists, the factors that determine Lumi's identity reach beyond t . Since this account is neutral with respect to matters of location and mereology, we may assume that time is a system of location, that Lumi is exactly and uniquely located at T , and that Lumi has different temporal parts at the different moments in T . This is a natural backdrop for the temporal non-locality of Lumi's identity. Assume, as is standard, that Lumi is a classical-mereological fusion of its temporal parts. Assume, moreover, that the identities of Lumi's temporal parts jointly determine

Lumi's identity—that is, Lumi is essentially composed of these temporal parts.¹⁰ It follows from these mereological assumptions that Lumi's identity is temporally non-local. Given that Lumi has different temporal parts that are exactly located at different moments in T , Lumi is not point-shaped. Moreover, since Lumi's temporal parts are collinear, Lumi is line-shaped. In sum, the dimensionality of the temporally extended object's shape matches the dimensionality of its interval. So far, so good.

Next, consider Lumi's first mode of persistence, as conceived of in the individuation framework: Lumi's identity is temporally local in that, for any moment, t , at which Lumi exists, the factors that determine Lumi's identity all obtain at t . Since this account is neutral with respect to matters of location and mereology, we may assume that time is a system of location and that Lumi is exactly located at each moment in T , but not at the whole of T . All attributes that determine Lumi's identity are instantiated at each moment at which Lumi exists. The temporal locality of identity fits naturally with the view that Lumi itself is exactly located at each of these moments. Of course, friends of the individuation framework are not forced to adopt multi-location. What matters here is just that they may do so. Now consider two moments in T , t_1 and t_2 . We assumed that Lumi is exactly located at each of them. Since t_1 and t_2 have a distance to each other, it follows that Lumi has this distance to itself. Hence, Lumi is not point-shaped. Similarly for collinearity. The moments in T are collinear. Since Lumi is exactly located at each moment in T , Lumi exhibits the pattern of collinearity, and hence Lumi is line-shaped. It follows that Lumi's individuation endurance does not correlate with Lumi's being point-shaped. This means that the individuation approach to persistence is not sufficient to capture the target difference between Lumi's first, non-spacelike mode of persistence and Lumi's second, spacelike mode of persistence. For if the individuation framework is combined with the conception of time as a system of location, then the individuation version of Lumi's first mode of persistence—individuation endurance—is not accompanied by Lumi's being point-shaped.

3 The geometrical framework of persistence

The difference between the two modes of persistence illustrated by the Lumi-case poses a serious challenge in the metaphysics of persistence. In the previous section,

¹⁰ See (Sattig 2023) for a non-classical mereological picture of structured objects with temporal parts.

I argued that the mainstream frameworks of persistence are ill-suited to capture the target difference. In this section, I will propose a new framework of persistence, and I will show that it succeeds where the others fail.

The mereological, locational, and individual frameworks of persistence are *domain-based* frameworks. They characterize different modes of persistence of the inhabitants of a system of time—the things in the system’s domain—in terms of different conceptions of the nature of these things. The mereological framework invokes different conceptions of what types of parts a thing has. The locational framework invokes different conceptions of what type of locational profile a thing has. The individuation framework invokes different conceptions of what determines a thing’s identity. Domain-based frameworks of persistence can be distinguished from *system-based* frameworks. The latter characterize different modes of persistence of a material thing in terms of different conceptions of the system of time in which the thing lives. While a domain-based framework characterizes modes of persistence of a thing that may be realized in the same type of system of time, a system-based framework characterizes modes of persistence that are based on different types of temporal system.

I will continue to conceive of time as having an intrinsic geometrical structure (see Section 2). Time has the structure of the one-dimensional Euclidean line. It is constituted by points or moments that stand in geometrical distance-relations to each other. Moreover, the points have a strict linear order that gives time its direction.

In Section 2, I distinguished between time’s intrinsic structure and time’s organizational functions. It is intuitively clear that time functions to organize material things in a certain fashion. Temporal organization has several aspects. Central aspects of temporal organization are that the denizens of time are temporally ordered and that they are temporally separated by certain amounts of time.

Having attained an understanding of what time’s functions are we can ask: *How* does time with its intrinsic geometrical structure perform its organizational functions? This is a substantive question. For there are different ways for a geometrically structured system to perform organizational functions. One way for time to organize its material domain is for time to transfer its geometrical structure to its inhabitants. This yields an isomorphism of geometrical structure between system and domain. In Section 2, I spelled out this answer in terms of the concept of exact location and I referred to this functional-geometrical system as a *system of location*. Material things are embedded in such a system by being exactly located at points or moments of time. Exact location is the relation by which geometrical attributes of temporal points are transferred to the material

inhabitants of time. For instance, a material thing, a , and a material thing, b , exist or obtain in separation by two seconds. What explains their temporal separation? Things are metrically separated in time in virtue of standing in relations of temporal distance to each other. Moreover, things inherit their temporal distances from their locations. Thus, a exists and b exists in separation by two seconds because a is located at a moment t_1 , b is located at another moment t_2 , and t_1 has the distance of two seconds to t_2 .

As I pointed out in Section 2, temporal being and temporal separation in a temporal system of location are analogous to spatial being and spatial separation in a spatial system of location. The standard view of how three-dimensional space, as we understand it pre-theoretically, organizes a domain of material things is that these things are exactly located at points or regions of a geometrically structured space and that intrinsic geometrical structure of the space is transferred to the inhabitants of the space by way of exact location.

A distinctly different way for a geometrically structured system to organize a material domain is the following.¹¹ While time has an intrinsic geometrical structure, time does not transfer any of its geometrical structure to its inhabitants. Time acts purely as an envelope of attribution of non-geometrical properties and relations. Time does not offer any attributes of material things. Time merely offers ways of having non-temporal attributes. More precisely, time is a system that performs its organizational functions by the operation of *relativization*, and hence time is a *system of relativization*. For instance, a material thing (an object or a state of an object), a , and a material thing, b , are embedded in time. What explains their temporal being? In a system of relativization, a and b are not located at any moment or interval. Instead, a and b exist or obtain *relative to* moments of the system. Suppose that a and b are momentary states that obtain in separation by two seconds. What explains their temporal separation? States are distributed in a system of relativization by virtue of obtaining relative to moments that stand in relations of temporal distance to each other. Thus, a obtains and b obtains in separation by two seconds because a obtains relative to t_1 , b obtains relative to t_2 , and t_1 has the distance of two seconds to t_2 . Owing to how a system of relativization performs its organizational functions, the material denizens of such a system do not strictly stand in any temporal relations of distance or precedence. Temporal relations do not enter any configurations of material things.

¹¹ The conception of time as a system of relativization is introduced in (Sattig 2025, chaps. 3 and 7).

Having distinguished two types of functional-geometrical temporal system, we can draw a distinction between two *system-based modes of persistence* of a material thing. The distinction is very simple. For a material thing to persist is for the thing to be extended in a functional-geometrical system of time. This is a neutral description of persistence. Since there are two types of functional-geometrical system of time, there are two ways for a material thing to be temporally extended: the thing is extended in a temporal system of location or the thing is extended in a temporal system of relativization. Assuming the standard picture of three-dimensional space as a system of location, being locationally temporally extended is spacelike since spatial extension is extension in a system of location. By contrast, being relativizationally temporally extended is non-spacelike. Being locationally temporally extended can thus be viewed as a form of perdurance, whereas being relativizationally temporally extended can be viewed as a form of endurance. This is the basic idea.

Spelling out this idea is a matter of determining what extension in one or the other functional-geometrical system of time amounts to. In a temporal system of location, a thing is temporally extended by being located at a temporally extended region of the system. This can happen in different ways. First, the thing is exactly located at one temporally extended region. Second, the thing is exactly located at several parts of a temporally extended region, but not at the whole region. The locational mode of persistence is neutral regarding these different ways of being exactly located at an extended region. What matters is just that temporal extension is a locational matter. By contrast, in a temporal system of relativization, a thing is temporally extended by existing or obtaining relative to multiple points or moments of the system. Fundamentally, nothing exists or obtains relative to an interval. To exist or obtain relative to an interval is just to exist or obtain relative to all moments that make up the interval. This is the relativizational mode of persistence.

The distinction between the locational and the relativizational modes of persistence is not domain-based in that it is not anchored in the nature of the denizens of time. It is system-based in that it is anchored in whether the denizens of time live in a system of location or in a system of relativization. The distinction between two types of system of time concerns the functional role of geometrical structure in a system of time. Accordingly, I will call the system-based framework of persistence the *geometrical framework*.

The geometrical framework offers the following account of the target difference. Recall that the task is to give an account of a difference concerning Lumi's persistence that is initially characterized by recourse to a difference concerning Lumi's shape.

Geometrical account of Lumi's first mode of persistence: the dimensionality of Lumi's shape does not match the dimensionality of Lumi's temporal interval because Lumi is temporally extended in a system of relativization.

Geometrical account of Lumi's second mode of persistence: the dimensionality of Lumi's shape matches the dimensionality of Lumi's temporal interval because Lumi is temporally extended in a system of location.

Let us begin with assessing the geometrical account of Lumi's second mode of persistence. Assuming that Lumi lives in a temporal system of location, Lumi is temporally extended by being location-related to some interval T . We saw in Section 2 that if Lumi is exactly and uniquely located at T and if Lumi has temporal parts at the different moments in T , then Lumi is line-shaped. In this case the dimensionality of Lumi's shape matches the dimensionality of Lumi's temporal interval. This picture is analogous to how Sumi is related to its one-dimensional spatial region. Further, we saw in Section 2 that if Lumi is multi-located at each moment in T , then Lumi is line-shaped as well. In sum, the locational mode of persistence in the geometrical framework works as expected.

Let us now turn to the geometrical account of Lumi's first mode of persistence. Assuming that Lumi lives in a temporal system of relativization, Lumi is temporally extended by existing relative to all moments in some interval T . Focus on two moments in T , t_1 and t_2 . They have distance d . Recall that if Lumi is exactly located at t_1 and t_2 in a system of location, then Lumi has d to itself. This is not the case in a system of relativization. That Lumi exists relative to t_1 and relative to t_2 does not entail that Lumi has d to itself. For no temporal distance-relations among moments are transferred to things existing relative to these moments. To emphasize, this result is not achieved by fiat. That the geometrical structure of time remains outside of the domain of time's inhabitants is part of the nature of a system of relativization. Moreover, since Lumi also has no parts with spatial distances among each other, Lumi has no parts with any distances to each other, and hence Lumi is point-shaped. Similarly for collinearity. The moments in T are collinear. As we saw, if Lumi is exactly located at each moment in T , then Lumi exhibits the pattern of collinearity, and hence Lumi is line-shaped. If, by contrast, Lumi exists relative to each moment in T , in a system of relativization, then Lumi does not exhibit the pattern of collinearity since this cross-temporal geometrical pattern cannot be inherited by any inhabitants of time. Putting together the geometrical accounts of Lumi's first and second modes

of persistence, we find that the geometrical framework of persistence is sufficient to capture the target difference between Lumi’s different modes of persistence.

The Lumi-case is very simple in that it treats Lumi as spatially zero-dimensional. This restriction has allowed us to focus on Lumi’s temporal dimension without getting distracted by spatial features. Most ordinary objects are not like Lumi. They are spatially three-dimensional. But it is easy to see how the geometrical framework of persistence extends to more familiar objects. Take an ordinary chair, Charlie. It has a three-dimensional shape and it exactly occupies a three-dimensional spatial region. The dimensionality of its shape matches the dimensionality of its spatial region. Now let the chair persist through time. Persistence brings extension of Charlie along a new dimension: time. Starting with three-dimensional space as a system of location—this is the standard picture—and assuming that the dimension of time is to be understood in geometrical-locational terms as well, the simplest and clearest way of ‘adding’ time to a three-dimensional spatial system of location is to conceive of space and time as forming a system of location whose points are spread out in four dimensions. If Charlie is temporally as well as spatially extended in such a four-dimensional system, then Charlie has parts that are interrelated by distances along four dimensions. If this is how Charlie lives in space and time, then Charlie has four-dimensional geometrical shapes. Thus, the dimensionality of Charlie’s shapes matches the dimensionality of Charlie’s exact region. This is a rough picture of the persistence of ordinary objects in a unified spatiotemporal system of location.

An alternative way of ‘adding’ time to a three-dimensional spatial system of location is to conceive of time as a one-dimensional system of relativization and to conceive of three-dimensional space as existing relative to each moment of time. This combination is a hybrid conception of a locational space and a relativizational time.¹² If Charlie is temporally and spatially extended in this hybrid system, then Charlie has spatial parts relative to moments. These parts are interrelated by geometrical spatial distances relative to moments. However, Charlie does not have any parts that are related by any temporal distances. No material things have any (positive) geometrical temporal distances in the hybrid system. It follows that Charlie has geometrical shapes of at most three dimensions in this system. Intuitively, while Charlie is temporally as well as spatially extended, the three-dimensional shapes that Charlie has relative to different moments never ‘add up’ to any four-dimensional shapes. Thus, the dimensionality of Charlie’s shapes does not match the dimensionality of Charlie’s exact region.

¹² See (Sattig 2025, chaps. 3 and 7) on the *r3d system* of space and time.

The geometrical framework of persistence accomplishes a task that the mereological, locational, and individuational frameworks are ill-equipped to handle. It is pre-theoretically sensible to draw a distinction between a material thing's modes of persistence by recourse to a difference concerning the dimensionality of the thing's shapes. The mainstream frameworks of persistence are insufficient to capture this difference. The geometrical framework gets the job done.

The mainstream frameworks of persistence were introduced as offering different explanations of a spacelike and a non-spacelike mode of persistence. The frameworks may be viewed as offering competing full explanations. Alternatively, they may be viewed as offering different partial explanations of modes of persistence. If the conceptual frameworks are viewed as partial explanations, then they may be combined in such a way that they illuminate different aspects of persistence. Given that we now have at least four different frameworks of persistence, the option of combining them raises the question as to which combinations of positions are sensible and of how the different packages compare with respect to their performance in dealing with various problems of persistence.

I will close this paper by characterizing the two packages of positions that I consider to be the simplest ones. First, space and time form a four-dimensional system of location. Material things live in this system. That is, persisting material things perdure geometrically. Moreover, a material thing lives in this system by being exactly located at a single spacetime region. That is, material things perdure locationally. Further, a material thing that exactly occupies a temporally extended spacetime region has temporal parts at the different parts of this region. That is, material things perdure mereologically. Finally, a material thing that exactly occupies a temporally extended spacetime region is such that its identity is determined in a temporally non-local fashion: what the thing is by its nature is determined by facts that reach beyond anything that is the case at a moment. That is, material things perdure individually. The first package thus combines geometrical, locational, mereological, and individuational perdurance.

Second, space is a system of location, whereas time is a system of relativization. They combine to form a hybrid system of temporally relativized three-dimensional space. Persisting material things live in this system by existing or obtaining relative to different moments. That is, material things endure geometrically. As regards locational persistence, material things neither perdure nor endure, since they do not live in a temporal system of location in the first place. Further, a material thing that exists relative to different moments does not have any temporal parts. Geometrically enduring material things do not need temporal parts to persist. That is, material things endure mereologically. Finally,

a material thing that exists relative to different moments is such that its identity is determined in a temporally local fashion: what the thing is by its nature is fully determined by facts that obtain relative to a moment. That is, material things endure individuationally. This is the second package. When it comes to mapping out the space of possible overall theories of persistence in light of the addition of the geometrical framework, the two packages outlined here may serve as natural starting points.¹³

References

- Eagle, Antony. 2016. "Multiple Location Defended." *Philosophical Studies* 173: 2215-2231.
- Gilmore, Cody 2008. "Persistence and Location in Relativistic Spacetime." *Philosophy Compass* 3: 1224-1254.
- Gilmore, Cody 2006. "Where in the Relativistic World Are We?" *Philosophical Perspectives* 20: 199-236.
- Hawley, Katherine. 2001. *How Things Persist*. Oxford University Press.
- Hofweber, Thomas & J. David Velleman. 2011. "How to Endure." *Philosophical Quarterly* 61: 37-57.
- Lewis, David. 1986. *On the Plurality of Worlds*. Blackwell Publishing.
- Parsons, Josh. 2008. "Theories of Location." In *Oxford Studies in Metaphysics*, edited by Dean. W. Zimmerman: 201-232.
- Sattig, Thomas. 2025. *How Time Passes*. Oxford University Press.
- Sattig, Thomas. 2023. "Persistence and Structure." *Philosophical Studies*, 182: 2425-2441.
- Sattig, Thomas. 2006. *The Language and Reality of Time*. Oxford University Press.
- Sider, Theodore. 2001. *Four-Dimensionalism: An Ontology of Persistence and Time*. Oxford University Press.
- Wasserman, Ryan. 2016. "Theories of Persistence." *Philosophical Studies* 173: 243-50.

¹³ For discussion of the geometrical framework of persistence I am indebted to David Braddon-Mitchell, Claudio Calosi, Damiano Costa, Giovanni Merlo, Cristian Mariani, Kristie Miller, Giuliano Torrenco, and the participants in my research seminar in the summer semester of 2024 at the University of Tübingen. Furthermore, I am grateful to my audience at the 45th International Wittgenstein Symposium 2024 for discussion of the distinction between the conception of time as a system of location and the conception of time as a system of relativization, on which the geometrical framework of persistence is based.